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G1G GPP
U1S S1502 S2192

(56) Documents cited
GB 2210977 A GB 2027198 A EP 0174627 A
US 4662212 A

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(54) Monitoring the concentration of carbon dioxide

(57) An apparatus for monitoring the concentration of carbon dioxide gas in a gaseous mixture, eg. from a beer cellar or vehicle exhaust gases, comprises a transmitting transducer 2 and a receiving transducer 3 positioned within the gaseous mixture to be monitored. A counter timer is provided for determining the time of flight of an ultrasonic pulse from the transmitting transducer to the receiving transducer. In order to correct the measurement for variations in temperature a temperature sensor 5 is provided for measuring the temperature of the gaseous mixture along the line of flight between the transducers 2, 3. The concentration of carbon dioxide in the gaseous mixture is then determined on the basis of the time of flight and the temperature.

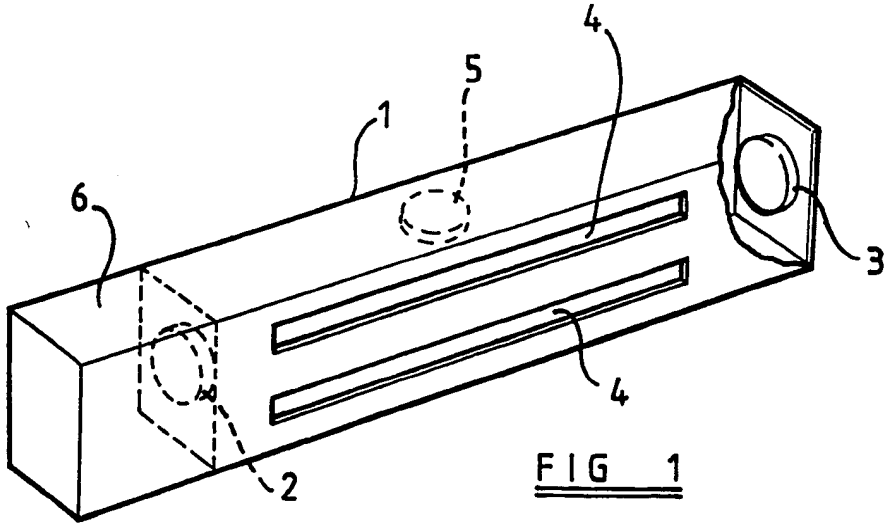

FIG 1

GB 2 257 255 A

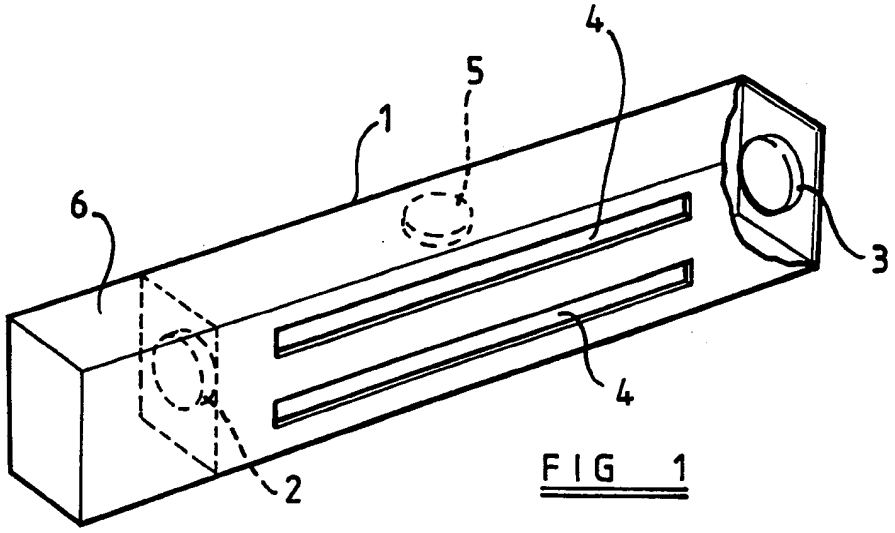

FIG 1

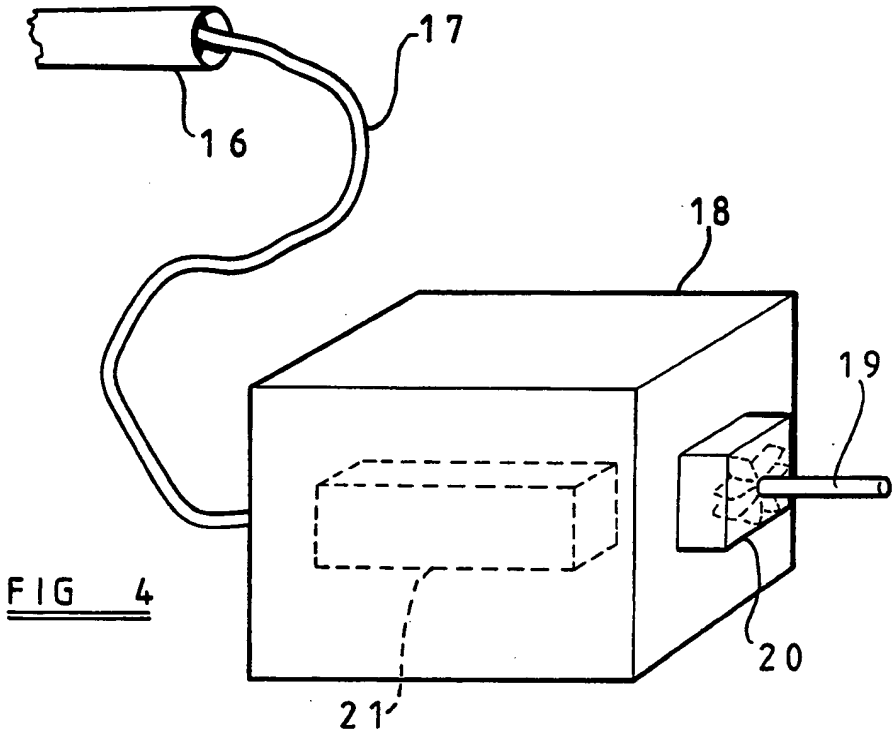

FIG 4

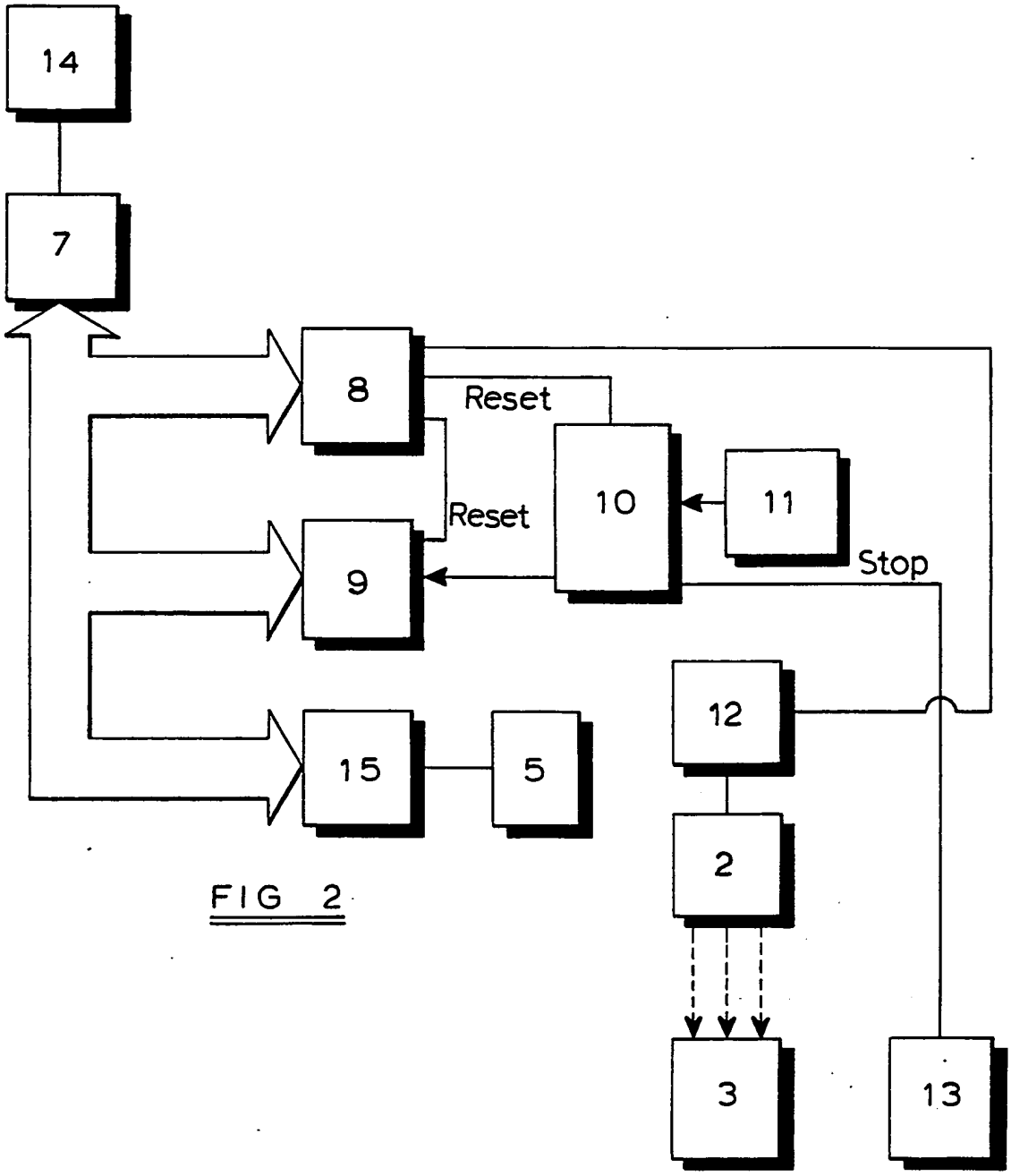

FIG 2

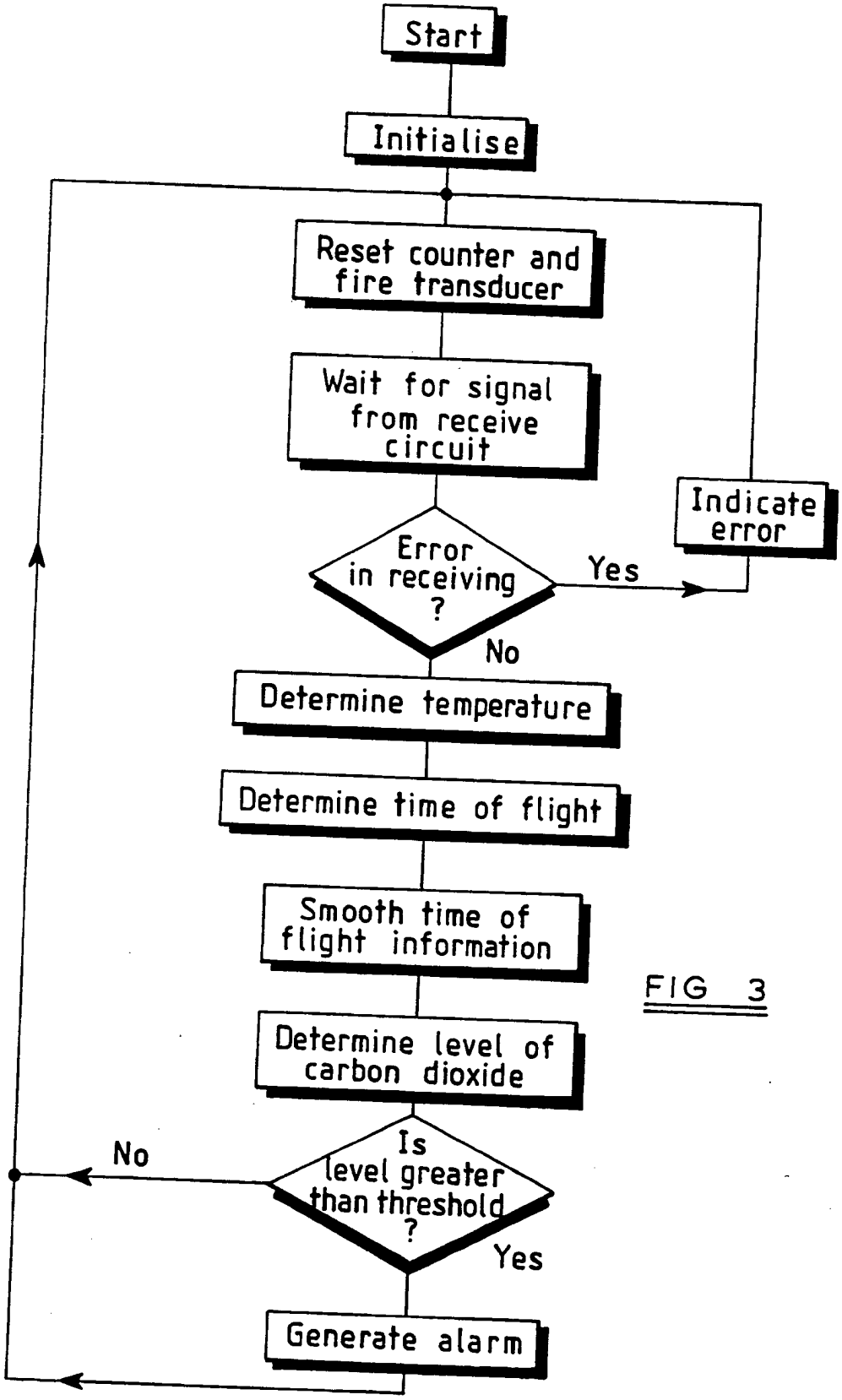
Start
Initialise
Reset counter and fire transducer
Wait for signal from receive circuit
Indicate error
Error in receiving ?
Yes
No
Determine temperature
Determine time of flight
Smooth time of flight information
Determine level of carbon dioxide
Is level greater than threshold ?
No
Yes
Generate alarm

FIG 3

APPARATUS FOR MONITORING CARBON DIOXIDE

The present invention relates to an apparatus for monitoring the concentration of carbon dioxide gas in a gaseous mixture and may be used, for example, to give a warning if the concentration of carbon dioxide monitored in the gaseous mixture exceeds a predetermined level.

It is known that concentrations of carbon dioxide gas in air above certain levels can lead to unconsciousness and even asphyxiation. Carbon dioxide gas can accumulate in enclosed spaces such as beer cellars or grain silos and is a potential hazard to workers in these environments. Carbon dioxide gas is also a potential problem in any place where fermentation occurs, such as in brewing or in the production of vinegar. The concentration of carbon dioxide gas in air can be measured, for example by infra-red absorption techniques, but the available equipment is expensive to purchase and is therefore not widely used. Thus, for safety reasons, there is a demand for an inexpensive apparatus for monitoring the concentration of carbon dioxide in air in enclosed spaces.

Additionally, it will shortly become necessary in the United Kingdom to test vehicle emission levels more rigorously, including the level of carbon dioxide in the exhaust gases, particularly for vehicles equipped with

catalytic converters. Again there is a demand for an inexpensive apparatus for measuring the concentration of carbon dioxide in exhaust gases.

It is an object of the present invention to provide apparatus for monitoring the concentration of carbon dioxide gas in a gaseous mixture such as air or vehicle exhaust gases on the basis of the time taken for a pulse of ultrasonic energy to pass through a part of the gaseous mixture to be monitored.

According to the present invention there is provided an apparatus for monitoring the concentration of carbon dioxide gas in a gaseous mixture comprising:

a transmitting transducer positioned within the gaseous mixture to be monitored, the transducer being adapted to transmit at least one pulse of ultrasonic energy;

a receiving transducer positioned within the gaseous mixture to be monitored, the receiving transducer being positioned a predetermined distance from the transmitting transducer and being adapted to receive the at least one pulse of ultrasonic energy;

means for determining the time of flight of the at least one ultrasonic pulse from the transmitting transducer to the receiving transducer;

means for determining the temperature of the gaseous mixture through which the at least one ultrasonic pulse is transmitted; and

means for determining, on the basis of the time of flight and the temperature, the concentration of carbon dioxide in the gaseous mixture.

The apparatus may include means for displaying the concentration of carbon dioxide in the gaseous mixture. Alternatively or additionally, the apparatus may include means for comparing the concentration of carbon dioxide in the gaseous mixture with a predetermined threshold and for generating an alarm if the concentration is above the threshold. The predetermined threshold may be variable. The alarm may be incorporated into the apparatus and/or located at a distance therefrom.

The transmitting transducer and the receiving transducer may be mounted within a housing. The housing may be provided with apertures so as to allow the gaseous mixture to pass into and out of the housing while restricting the effects of any disturbances in the mixture.

The means for determining the time of flight may include clock means adapted to generate pulses at a predetermined frequency and counter means for determining the number of clock pulses during the flight of the at least one pulse of

ultrasonic energy from the transmitting transducer to the receiving transducer.

The time of flight may be determined by a moving average of a predetermined number or measurements of the time of flight for a pulse of ultrasonic energy.

It may be desirable for the concentration of carbon dioxide not to be determined until at least a predetermined number of measurements of the time of flight for a pulse of ultrasonic energy has been effected.

The means for determining the temperature of the gaseous mixture through which the at least one ultrasonic pulse is transmitted may include a temperature sensor positioned adjacent to the line of flight of the at least one ultrasonic pulse from the transmitting transducer to the receiving transducer. The temperature sensor may be positioned substantially mid-way between the transmitting transducer and the receiving transducer.

The apparatus may include means for determining whether the receiving transducer has received a pulse of ultrasonic energy within a predetermined time of the transmitting transducer transmitting said pulse and for generating a warning if the pulse has not been received.

The concentration of carbon dioxide in the gaseous mixture may be determined as follows:

$$\textit{weight percent } CO_2 = \left(\frac{\frac{d}{t} - S_1 \times \sqrt{1 + \frac{T}{273}}}{S_2 \times \sqrt{1 + \frac{T}{273}} - S_1 \times \sqrt{1 + \frac{T}{273}}} \right) \times 100$$

where:

d = distance in metres between the transducers

t = time of flight in seconds

S_1 = speed of sound in the gaseous mixture at 0°C (331.45 metres per second for air)

S_2 = speed of sound in pure CO_2 at 0°C (259 metres per second)

T = temperature in degrees Celsius

For a better understanding of the present invention and to show more clearly how it may be carried into effect reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a diagrammatic perspective view of one embodiment of an apparatus according to the present invention for monitoring the concentration of carbon dioxide gas in a gaseous mixture such as air;

Figure 2 is a block diagram of one embodiment of an electronic circuit for use in the apparatus shown in Figure 1;

Figure 3 is a diagrammatic representation of the steps involved in determining the concentration of carbon dioxide gas in a gaseous mixture such as air by means of an apparatus according to the present invention; and

Figure 4 is a diagrammatic representation of an apparatus according to the present invention for monitoring the concentration of carbon dioxide gas in vehicle exhaust gases.

As shown in Figure 1, an apparatus for monitoring the concentration of carbon dioxide gas in a substantially stationary gaseous mixture such as air, for example in a beer cellar, comprises a housing 1 such as a tube of plastics material having rigidly mounted therein two ultrasonic transducers in the form of a transmitting transducer 2 and a receiving transducer 3. The transducers 2, 3 are mounted in the housing so as to be in the air to be monitored and are positioned a predetermined distance apart, for example 300 mm. The housing 1 is provided with apertures 4 in the form of holes and/or slots so as to allow air containing any carbon dioxide to flow into and out of the housing while restricting the effects of any disturbances, such as draughts, in the air.

Also mounted within the housing 1, substantially mid-way between the two transducers and adjacent to the line of flight of pulses of ultrasonic energy between the transducers 2 and 3, is a temperature sensor 5 for measuring the temperature of the air along the line of flight.

Mounted adjacent to the housing 1, for example at one end thereof, is a container 6 for the electronic circuit required to determine the concentration of carbon dioxide gas in the air within the housing.

We have found, however, that heat generated by the electronic circuit can in some circumstances affect the temperature within the housing 1 and it may, therefore, be desirable to separate the housing from the container 6 for the electronic circuit.

The electronic circuit is shown in more detail in Figure 2 and comprises transmitting transducer 2, receiving transducer 3 and temperature sensor 5, the operation of the transducers being controlled by way of a microprocessor 7, as shown in more detail in Figure 3. The microprocessor 7 commences operation as soon as power is turned on to the apparatus and proceeds with an initialisation step in which variables such as the predetermined distance between the transducers 2, 3, the number of pulses of ultrasonic energy that are to be fired and the width or duration of each

pulse, and the predetermined threshold at which to trigger an alarm are read from memory. Although it is not shown in the drawings, if desired these variables may be altered by way of a programming device that can be plugged into an interface provided in the apparatus, or can be altered by exchanging one read-only memory (ROM) for another, or by any other suitable means.

Once the initialisation step is completed, the microprocessor 7 triggers a latch 8 to reset a counter 9, for example a 16 bit counter, to reset a latch 10 receiving pulses from a clock 11, such as a 10 MHz clock, so as to pass the clock pulses to the counter 9, and to activate a transmit circuit 12 so as to cause the transmitting transducer 2 to emit or fire a pulse of ultrasonic energy. In some environments, for example where there is high humidity, the ultrasonic pulse is quickly attenuated and this may need to be overcome by firing a sequence of a plurality of pulses which has the effect of increasing the power of the ultrasonic wave generated.

The ultrasonic pulse passes along the housing 1 and is detected by receiving transducer 3 which activates a receive circuit 13 so as to trip the latch 10 and block the transmission of clock pulses to the counter 9. In the event that the receive circuit 13 is not activated within a predetermined time, this is detected by the microprocessor 7 and an appropriate message or signal

warning of the fault is shown on a display 14 and/or an audible warning is given by means of an alarm (not shown) which may be incorporated into the apparatus and/or located at a distance therefrom.

Once the counter 9 has been stopped, the microprocessor 7 determines the temperature from temperature sensor 5 by way of an interface 15, calculates the time of flight of the ultrasonic pulse between the two transducers 2, 3 and smoothes the time of flight information in order to avoid activating the alarm unnecessarily and/or to avoid displaying an inaccurate level of carbon dioxide. Thus smoothing is effected by employing a moving average of at least a predetermined number of measurements of the time of flight for a pulse, discarding the oldest measurement as a new measurement becomes available once the required number of measurements is available. In practice, an average is established initially for a sequence of, say, five pulses and this can be built up as desired to a moving average of up to thirty pulses where, as data for each new pulse is obtained, data for the oldest pulse is discarded.

The percentage by weight of carbon dioxide in the gaseous mixture such as air within the housing is determined from the equation:

$$\text{weight percent } CO_2 = \left(\frac{\frac{d}{t} - S_1 \times \sqrt{1+\frac{T}{273}}}{S_2 \times \sqrt{1+\frac{T}{273}} - S_1 \times \sqrt{1+\frac{T}{273}}} \right) \times 100$$

where:

d = distance in metres between the transducers

t = time of flight in seconds

S_1 = speed of sound in the gaseous mixture at 0°C (331.45 metres per second for air)

S_2 = speed of sound in pure CO_2 at 0°C (259 metres per second)

T = temperature in degrees Celsius

The percentage by weight of carbon dioxide, when determined, can be used in a number of ways. It can be used directly, or indirectly following conversion to percentage by volume of carbon dioxide, to trigger the alarm if the amount of carbon dioxide exceeds a predetermined threshold, for example 0.5 percent by volume, the alarm being incorporated into the apparatus and/or located at a distance therefrom as described above. The level of carbon dioxide determined can alternatively or additionally be used to display the level of carbon dioxide in the air or other gaseous mixture on display 14.

In order to determine the concentration of carbon dioxide gas in vehicle exhaust gases an apparatus such as that

shown in Figure 1 is incorporated in the apparatus shown in Figure 4. Figure 4 shows a vehicle exhaust pipe 16 having a probe 17 inserted therein. The probe 17 leads to a chamber 18 for accumulating the exhaust gases, the volume and any internal arrangements of the chamber being such that the flow rate of gas within at least that part of the chamber where the transducers are located is substantially stationary. Exhaust gases and other any gas are removed from the chamber 18 through an outlet tube 19, optionally by way of a fan shown diagrammatically at 20.

Positioned within the chamber 18 is an apparatus 21 for monitoring the concentration of carbon dioxide as described with reference to Figure 1. The apparatus therefore does not require any detailed description except to note that the electronic controls need not be mounted at one end of the container 6, but can be mounted remote from the apparatus shown in Figure 4. The concentration of carbon dioxide gas is determined in the same manner as described with reference to Figures 2 and 3 except that the speed of sound requires to be modified to correspond to that for exhaust gases.

CLAIMS

1. An apparatus for monitoring the concentration of carbon dioxide gas in a gaseous mixture comprising:

a transmitting transducer positioned within the gaseous mixture to be monitored, the transducer being adapted to transmit at least one pulse of ultrasonic energy;

a receiving transducer positioned within the gaseous mixture to be monitored, the receiving transducer being positioned a predetermined distance from the transmitting transducer and being adapted to receive the at least one pulse of ultrasonic energy;

means for determining the time of flight of the at least one ultrasonic pulse from the transmitting transducer to the receiving transducer;

means for determining the temperature of the gaseous mixture through which the at least one ultrasonic pulse is transmitted; and

means for determining, on the basis of the time of flight and the temperature, the concentration of carbon dioxide in the gaseous mixture.

2. An apparatus as claimed in claim 1 and including means for displaying the concentration of carbon dioxide in the gaseous mixture.

3. An apparatus as claimed in claim 1 or 2 and including means for comparing the concentration of carbon dioxide in the gaseous mixture with a predetermined threshold and for generating an alarm if the concentration is above the threshold.

4. An apparatus as claimed in claim 3, wherein the predetermined threshold is variable.

5. An apparatus as claimed in claim 3 or 4, wherein the alarm is incorporated into the apparatus.

6. An apparatus as claimed in claim 3, 4 or 5, wherein the alarm is located at a distance from the remainder of the apparatus.

7. An apparatus as claimed in any preceding claim, wherein the transmitting transducer and the receiving transducer are mounted within a housing.

8. An apparatus as claimed in claim 7, wherein the housing is provided with apertures so as to allow the gaseous mixture to pass into and out of the housing while restricting the effects of any disturbances in the mixture.

9. An apparatus as claimed in any preceding claim, wherein the means for determining the time of flight includes clock means adapted to generate pulses at a predetermined frequency and counter means for determining the number of clock pulses during the flight of the at least one pulse of ultrasonic energy from the transmitting transducer to the receiving transducer.

10. An apparatus as claimed in any preceding claim, wherein the time of flight is determined by a moving average of a predetermined number of measurements of the time of flight for a pulse of ultrasonic energy.

11. An apparatus as claimed in any preceding claim, wherein the concentration of carbon dioxide is not determined until at least a predetermined number of measurements of the time of flight for a pulse of ultrasonic energy has been effected.

12. An apparatus as claimed in any preceding claim, wherein the means for determining the temperature of the gaseous mixture through which the at least one ultrasonic pulse is transmitted includes a temperature sensor positioned adjacent to the line of flight of the at least one ultrasonic pulse from the transmitting transducer to the receiving transducer.

13. An apparatus as claimed in claim 12, wherein the temperature sensor is positioned substantially mid-way between the transmitting transducer and the receiving transducer.

14. An apparatus as claimed in any preceding claim and including means for determining whether the receiving transducer has received a pulse of ultrasonic energy within a predetermined time of the transmitting transducer transmitting said pulse and for generating a warning if the pulse has not been received.

15. An apparatus as claimed in any preceding claim, wherein the concentration of carbon dioxide in the gaseous mixture is determined as follows:

$$\textit{weight percent } CO_2 = \left(\frac{\frac{d}{t} - S_1 \times \sqrt{1 + \frac{T}{273}}}{S_2 \times \sqrt{1 + \frac{T}{273}} - S_1 \times \sqrt{1 + \frac{T}{273}}} \right) \times 100$$

where:

d = distance in metres between the transducers

t = time of flight in seconds

S_1 = speed of sound in the gaseous mixture at 0°C (331.45 metres per second for air)

S_2 = speed of sound in pure CO_2 at 0°C (259 metres per second)

T = temperature in degrees Celsius

16. An apparatus for monitoring the concentration of carbon dioxide gas in a gaseous mixture substantially as hereinbefore described with reference to, and as shown in, Figures 1, 2 and 3 or Figure 4 of the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
9213196.0

Relevant Technical fields

(i) UK Cl (Edition K) G1G (GPP)

5 G01N (29/00, 29/02)

(ii) Int Cl (Edition)

Search Examiner
J M MCCANN

Databases (see over)

(i) UK Patent Office

(ii) ONLINE: WPI

Date of Search
4 AUGUST 1992

Documents considered relevant following a search in respect of claims

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2210977 A	(GEC) page 2 line 14 to page 3 line 5 and page 6 last paragraph	1, 10, 12, 13
X	GB 2027198 A	(S.S.O.S. SUBSEA OIL) Figure 1 and page 1 lines 64 to 69	1, 7, 8, 12, 13
X &	EP 0174627	(SUMITO BAKELITE CO LTD) page 3 last paragraph, page 4 lines 4 to 14, page 5 lines 14 to 24 and Figure 2	1,2,7,8 12,13,15
X &	US 4662212	(NOGUCHI) Figure 2 column 2 lines 16 to 26 and lines 54 to 63	1,2,7,8 12,13,15

SJJ - doc99\f11000265

SF2(p)

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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